PB-229 749

STORAGE FOR MUNICIPAL AND INDUSTRIAL WATER SUPPLY AND STREAM QUALITY CONTROL SAND, COPAN, BIRCH, CANDY, AND SKIATOOK RESERVOIRS LOWER VERDIGRIS RIVER BASIN OKLAHOMA

Public Health Service
Dallas, Texas

December 1961

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PB 229 749

STORAGE FOR

MUNICIPAL AND INDUSTRIAL WATER SUPPLY

AND

STREAM QUALITY CONTROL

SAND, COPAN, BIRCH, CANDY, AND SKIATOOK RESERVOIRS

LOWER VERDIGRIS RIVER BASIN

OKLAHOMA

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service, Region VII
Dallas, Texas

In Cooperation with the

DEPARTMENT OF THE ARMY
U. S. Army Engineer District - Tulsa, Oklahoma

DECEMBER 1961

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I. INTRODUCTION

Authority

The District Engineer, U. S. Army Engineer District, Tulsa, in a letter, dated June 10, 1958, requested the Public Health Service to " . . . provide data on quality of water, water pollution and minimum flow requirements for pollution abatement and beneficial effects in the lower Verdigris River Basin," with consideration to be given to Skiatook, Avant, Sand, and Copan Reservoir sites.

A Memorandum of Agreement between the Secretaries of the Department of Health, Education, and Welfare and the Army, dated November 4, 1958, established a working agreement in regard to the Water Supply Act of 1958. The scope of the investigation was enlarged to conform to the general policy established by that agreement. Subsequently, as requested, a report of that investigation, entitled "Storage for Municipal and Industrial Water Supply, Copan, Sand, Avant and Skiatook Reservoirs and Stream Quality Considerations, Lower Verdigris River Basin," was prepared and submitted in June 1961.

In a letter dated November 8, 1961, the U. S. Army Engineer District, Tulsa, provided revised data, substituting Birch and Candy Reservoir sites for the Avant Reservoir site and requested a supplement to the June 1961 report.

Purpose and Scope

This report presents data and information relevant to the determination of water requirements, to the year 2020, for municipal, industrial, and water quality control purposes in the lower Verdigris River. An estimate of the annual benefits which could be ascribed to storage allocated to these purposes is evolved from the projected economic developments and anticipated requirements for water supply and stream quality preservation.

Acknowledgments

The cooperation and assistance of many persons and agencies are gratefully acknowledged. Special appreciation is expressed to the following:

Oklahoma State Department of Health
Oklahoma Water Resources Board
Tulsa Metropolitan Area Planning Commission
Director, Department of Water and Sewerage, Tulsa, Oklahoma
City Manager, Bartlesville, Oklahoma

II. SUMMARY AND CONCLUSIONS

Summary

1. There are five reservoir sites under consideration in the lower Verdigris River system. Skiatook on Hominy Creek, Birch on Birch Creek, and Candy on Candy Creek are on the Bird Creek watershed just north of Tulsa, Oklahoma, while Sand on Sand Creek and Copan on Caney Creek are located west and north (respectively) of Bartlesville, Oklahoma, on the Caney River watershed.

2. Water from storage in the proposed five reservoir system would be available in Caney River - Bird Creek basins of the lower Verdigris River system and adjoining areas including all or part of Tulsa, Osage, Creek, and Washington Counties, Oklahoma, the area under consideration. Major water demand centers within this area are Tulsa and Bartlesville.

3. In addition to present sources, a major potential source of future water supply for the study area is the Oologah Reservoir, now under construction on the Verdigris River some 40 miles north of Tulsa. Secondary sources are the existing Hulah Reservoir on the upper Caney River and the projects under study herein.

Conclusions

1. Projections to the year 2020 indicate an increase in the study area population from approximately 460,000 in 1960 to 1,600,000 in 2020. The population served by municipal water works systems would expand from 365,000 in 1960 to 1,530,000 in 2020.

2. Expansion of the oil refining and petrochemical industries is projected in the study area.

3. Water quality data for the streams to be impounded are limited. Indications are that releases of oil field brines to the streams in this area could increase the total solids and chlorides concentrations so that the quality of water to be impounded would be unsuitable for municipal and most industrial water supply purposes. However, with continued

improvement in the control by state agencies of manmade pollution sources, the quality of the water that would be stored in study projects is expected to be satisfactory, after normal treatment, for general municipal and industrial use.

4. Projected (2020) demands within the study area (stated as the average rate of use during the year of maximum demand) are:

Municipal	270 mgd
Industrial	220 mgd

5. Storage must be provided at the proposed project sites for stream quality control by flow regulation of the lower Verdigris River basin.

6. In the absence of a detailed study which is desirable, it is assumed that 50 percent of the water supply yield available in the five study projects should be allocated for stream quality control. On this basis, the following benefits are ascribed to storage in the proposed projects.

	Yield -- mgd		Average Annual Benefits ($1,000)	
Reservoir	Municipal & Industrial Water Supply	Flow Regulation For Quality Control	Municipal & Industrial Water Supply	Flow Regulation For Quality Control
Copan	14.2	17.8	280	357
Sand	7.8*	4.2	131	70
Birch	3	3	33.5	33.5
Candy	2	2	46	46
Skiatook	14	14	327	327
Total	41.0	41.0		

*Yield requested by Bartlesville.

7. Stream flow regulation for quality control by use of water supply storage in the study projects will benefit the lower Verdigris River system. The benefits for water quality control can be considered widespread.

III. DESCRIPTION OF PROJECTS

Location

The five projects under consideration are located in northeastern Oklahoma as shown on Figure 1 in the Caney River and Bird Creek basins. Table III-1 displays data for these lower Verdigris River watersheds.

Two project sites, Sand and Copan, are situated in the Caney River basin near Bartlesville, Oklahoma, while the other three sites, Skiatook, Birch, and Candy, are on tributaries to Bird Creek northwest of Tulsa, Oklahoma.[1/]

Stream Flow[2/]

Stream flow data for the Caney River and Bird Creek basins, together with the lower Verdigris River and Arkansas River (at Tulsa) are summarized in Table III-2.

Water Quality[3/]

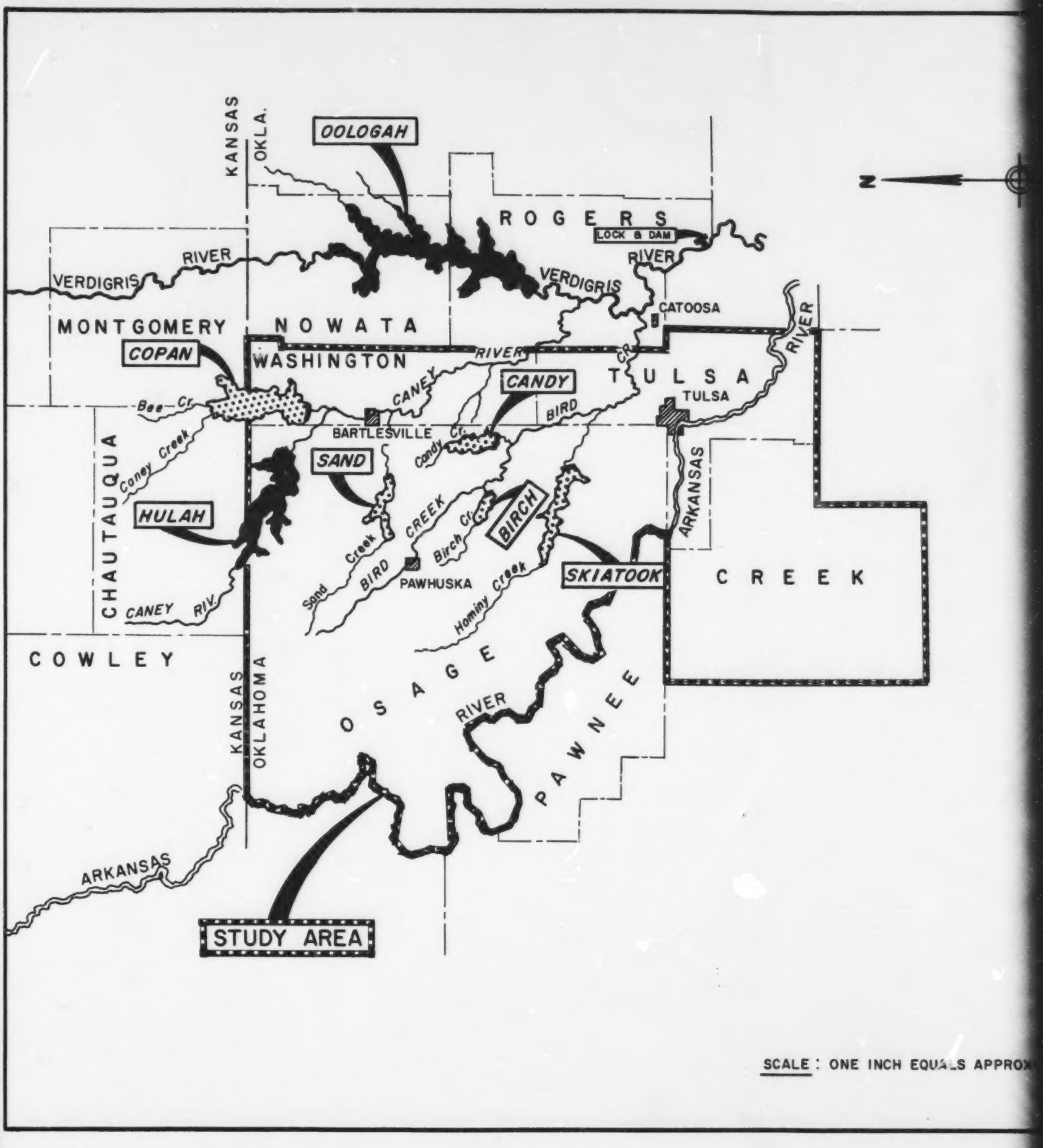
Only a limited amount of water quality data are available for the reaches of the streams adjoining the proposed project sites. Oil field brines are released to the streams in the area. From time to time, these releases have rendered water in various streams unsuitable for municipal and most industrial purposes by increasing the dissolved solids and chlorides concentration beyond the limits set in the Public Health Service Drinking Water Standards.[4/] However, abatement of this pollution is being undertaken by State authorities. Water to be impounded at these sites is expected to be suitable for most water supply purposes after treatment.

A resume of water quality data for the Caney River and Bird Creek basins, as well as the lower Verdigris River and Arkansas River (at Tulsa) is presented in Table III-3.

Pertinent Data[1/]

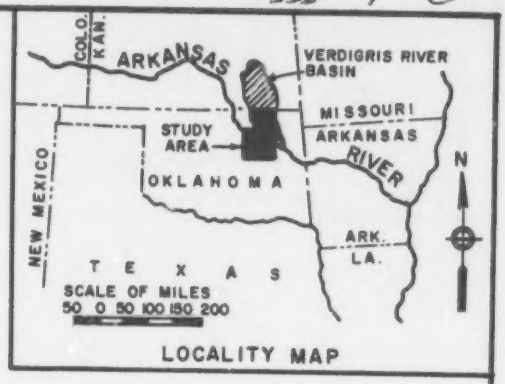
The proposed multipurpose dams under consideration will be of the earthfill type. Information concerning design features is shown in Table III-4.

There are two reservoirs in the lower Verdigris system, Hulah and Oologah, which markedly affect water supply planning for the study projects. Pertinent data for these reservoirs are displayed in Table III-5.



SCALE : ONE INCH EQUALS APPROX

III - 1 - a



LOCALITY MAP

LEGEND

RESERVOIR COMPLETED OR UNDER CONSTRUCTION.

PROPOSED RESERVOIR.

AUTHORIZED LOCK AND DAM.

SCALE : ONE INCH EQUALS APPROXIMATELY 16 MILES.

SAND, COPAN, BIRCH, CANDY & SKIATOOK RESERVOIRS-CANEY RIVER-BIRD CREEK BASINS

VICINITY MAP

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PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE 1

Table III-1

Watershed Data 1/
Caney River and Bird Creek Basins

Water Course	Tributary To	Drainage Area (Sq.Mi.)	Length (Miles)	Source	Mouth	Major Tributaries
Caney Creek	Caney River	515	60	Elk County, Kansas	Washington County, Okla. Caney River Mi. 80.5	Bee Creek
Sand Creek	Caney River	240	50	Osage County, Oklahoma	Washington County, Okla. Caney River Mi. 63.7	None
Caney River	Verdigris River	2,111	155	Elk County, Kansas	Rogers County, Oklahoma Verdigris River Mi. 78.3	Caney Creek Sand Creek
Candy Creek	Bird Creek	51	10*	Osage County, Oklahoma	Osage County, Oklahoma Bird Creek Mi. 53	None
Birch Creek	Bird Creek	67	15*	Osage County, Oklahoma	Osage County, Oklahoma Bird Creek Mi. 64	None
Hominy Creek	Bird Creek	415	60*	Osage County, Oklahoma	Tulsa County, Oklahoma Bird Creek Mi. 29	None
Bird Creek	Verdigris River	1,137	106	Osage County, Oklahoma	Rogers County, Oklahoma Verdigris River Mi. 63.6	Candy Creek, Birch Creek, Hominy Creek
Verdigris River	Arkansas River	8,303	350	Greenwood County, Kansas	Muskogee County, Oklahoma Arkansas River Mi. 460	Fall River, Elk River, Big Hill Cr., Caney River & Bird Creek

*Estimate

Table III-2

Stream Flow Data Caney River, Bird Creek, And Lower Verdigris River Systems 2/

Station & Location	Drainage Area sq. mi.	Average Flow, cfs Length of Records	Minimum Monthly Flow, cfs Date	Maximum Monthly Flow, cfs Date
Caney Creek near Copan, Oklahoma, mile 18.9	424	240 14 yrs.	0 Sev. mos.	2,499 4-44
Caney River near Hulah Reservoir, mile 95.3	736	413 13 yrs.	0 Sev. mos.	3,977 4-44
Bird Creek at Avant, Oklahoma, mile 54.2	364	162 12 yrs.	0 Sev. mos.	2,648 6-57
Hominy Creek near Skiatook, mile 16.8	340	159 13 yrs.	0 Sev. mos.	2,087 5-57
Bird Creek near Sperry, mile 25.0	905	474 19 yrs.	0 Sev. mos.	10,670 5-43
Verdigris River near Inola, mile 48.8	7,911	3,992 13 yrs.	17.0 9-54	41,400 6-57
Arkansas River at Tulsa, mile 523.7	74,615	6,304 32 yrs.	125 10-56	61,100 6-57

Table III-3

Water Quality 3/
Caney River, Bird Creek, and
Lower Verdigris River Systems

	Caney Creek	Sand Creek	Caney River	Candy Creek	Birch Creek	Hominy Creek	Bird Creek	Verdigris River	Ark. River	Cotton Creek
Location	*	Near Okesa	Near Hulah Site	Near Avant	Near Skiatook	Near Skiatook	@ Barnsdall	Near Inola	Tulsa	Near Copan
Temperature	*	71	55	58	57	----	56	----	----	77
Ca	*	32	63	61	56	25	60	42	119	96
Mg	*	4.9	11	10	12	6.8	12	9.4	33	16
Na&K	*	11	17	35	47	51	31	65	666	63
HCO_3	*	102	222	178	170	63	203	103	157	276
CO_3	*	0	0	0	0	0	0	0	----	0
SO_4	*	---	29	32	29	----	30	35	164	40
Cl	*	15	19	64	85	103	48	114	1,120	124
NO_3	*	---	1.1	0.8	1.1	----	1.7	4.2	3.0	0.2
TDS	*	---	277	326	364	----	308	368	2,300	544
Hardness	*	100	222	193	239	90	231	144	432	386
Spec. K	*	227	447	543	595	464	516	613	3,970	883
pH	*	7.1	8.1	7.7	7.5	7.6	7.6	7.8**	8.0**	7.8
Sample date		6-7-55	4-9-52	4-9-52	4-9-52	3=16-53	4-9-52	Oct.52 to Sept. 53	Oct.52 to Sept. 53	5-6-52
Class of Analysis		typical	typical	typical	typical	typical	typical	weighted average	weighted average	typical

* No data available
** Approximate

All data in parts per million (ppm) except Temperature - ^{o}F, Specific conductance (spec.K)- micromhos, and pH.

Table III-4

Pertinent Data - Proposed Reservoirs [1/]
Caney River and Bird Creek Basins

Features	Proposed Reservoirs				
	Copan	Sand	Skiatook	Birch	Candy
Stream	Caney Creek	Sand Creek	Hominy Creek	Birch Creek	Candy Creek
River Miles Above Mouth	9.6	19.1	14.3	0.8	1.0
Drainage Area - Square Miles	501	137	354	66	50
Type of Dam	Earthfill	Earthfill	Earthfill	Earthfill	Earthfill
Elevations - ft, msl:					
Conservation Pool	722.0	766.0	680.0	741.5	700.0
Flood Control Pool	737.5	786.0	703.0	764.5	720.0
Spillway Crest	702.5 [a/]	786.0	668.0 [a/]	764.5	720.0
Top of Dam	746.5	808.0	715.5	789.0	744.5
Volumes - Acre-feet:					
Conservation Pool	90,000	35,000	70,000	15,000	12,000
Flood Control	175,700	51,700	141,000	29,800	23,100
Sediment	12,000	4,300	12,000	2,000	1,400
Total	277,700	91,000	223,000	46,800	36,500
Water Supply Yield - mgd	32	12	28	6	4

Total Water Supply Yield = 82 mgd

a/ Controlled spillway.

Table III-5

Pertinent Data [1/]
Hulah and Oologah Reservoirs
Lower Verdigris River System

Features	Hulah (Existing Reservoir)	Oologah (Under Construction) Initial Development	Oologah (Under Construction) Ultimate Development
Stream	Caney River	Verdigris River	Verdigris River
River Miles Above Mouth	96.2	90.2	90.2
Drainage Area - Square Miles	732	4,339	4,339
Type of Dam	Earthfill	Earthfill	Earthfill
Elevations - ft, msl:			
Conservation Pool	733.0	608.0	638.0
Flood Control Pool	765.0	651.0	661.0
Spillway Crest	740.0 [a/]	651.0	640.0 [a/]
Top of Dam	779.5	687.0	687.0
Volumes - Acre-feet:			
Conservation Pool	33,400	48,700	544,100
Flood Control	257,800	963,000	965,600
Sediment	12,800 [b/]	22,800 [b/]	58,400 [b/]
Total	292,500	1,021,000	1,519,000
Water Supply Yield - mgd	10 [c/]	47	154

[a/] Controlled spillway.
[b/] Sediment storage consists of permanent pool and portions of conservation and flood control pools.
[c/] Includes only municipal and industrial supply.

IV. DESCRIPTION OF STUDY AREA

Location and Boundaries

The study area is located in the northeastern portion of the State of Oklahoma. As shown in Figure 1, the area consists of the four adjoining counties which lie to the south and east of the intersection of the Kansas-Oklahoma border and the Arkansas River. The four counties studied include the Tulsa Standard Metropolitan Statistical Area (SMSA) consisting of Osage, Creek, and Tulsa Counties, and the Bartlesville area, Washington County.

Geography

The area under investigation consists of three general land resources areas. These are the Bluestem (Limestone - Flint Hills) region, the Cross Timbers region, and the Cherokee Prairie region.[5,6]

The Bluestem region includes most of Osage County. The terrain is rolling to hilly with steep breaks and escarpments adjacent to the stream valleys.[5] Grades of streams rising in the region are as much as 20 feet per mile.[5]

The Cross Timbers region includes Creek County, Oklahoma and the southeastern portion of Osage County, Oklahoma. The terrain is rolling to hilly with numerous low hills and ridges.[5] Stream valleys are moderately to deeply entrenched.[5]

The Cherokee Prairie region includes Tulsa and Washington Counties, Oklahoma. The terrain is gently rolling to nearly level with low hills.[5] East-facing escarpments and ridges rise from the low plain. The streams have narrow channels and broad, low-lying terraces and bottoms.[5]

Climate[5,7]

The average annual temperature of the study area ranges from 54° to 61° F; the average annual rainfall ranges from 30 to 40 inches; April to September rainfall averages about 25 inches; and the growing season ranges from 170 to 196 days.

Principal Communities and Industries

Tulsa and Bartlesville, are the principal cities in the study area. Agriculture, mining, and manufacturing industries require most of the resources of the region. Petroleum refining is the most significant water using manufacturing activity in the study area.

V. ECONOMICS AND POPULATION

Municipal and industrial water demands will be centered at the principal cities in the study area. Industrial expansion, population growth, and the accompanying increase in water use depend on growth factors, both inside and outside the study area. Therefore, an examination of the economic environment is necessary, particularly in relation to national and competitive regional factors. Details of the economic environment of the study area are appended (Exhibit A).

Population

The population of the study area has increased fourfold in the past 50 years. Most of this increase was registered in incorporated areas. The municipal population of the study area increased from 48,772 in 1910 to 365,120 in 1960. Table V-1 displays these trends.

Table V-1

Population 1910-1960 16/
Four County Study Area

Study Area	1910	1920	1930	1940	1950	1960
Total	98,808	235,041	326,800	319,927	360,780	461,321
Municipal	48,772	151,140	222,050	221,636	267,789	365,120
Tulsa SMSA*						
Total	81,319	208,039	299,023	289,368	327,900	418,974
Municipal	39,353	132,620	203,513	201,591	243,306	331,648
Bartlesville Area (Washington County)						
Total	17,484	27,002	27,777	30,559	32,880	42,347
Municipal	9,419	18,570	18,537	20,045	24,483	33,472

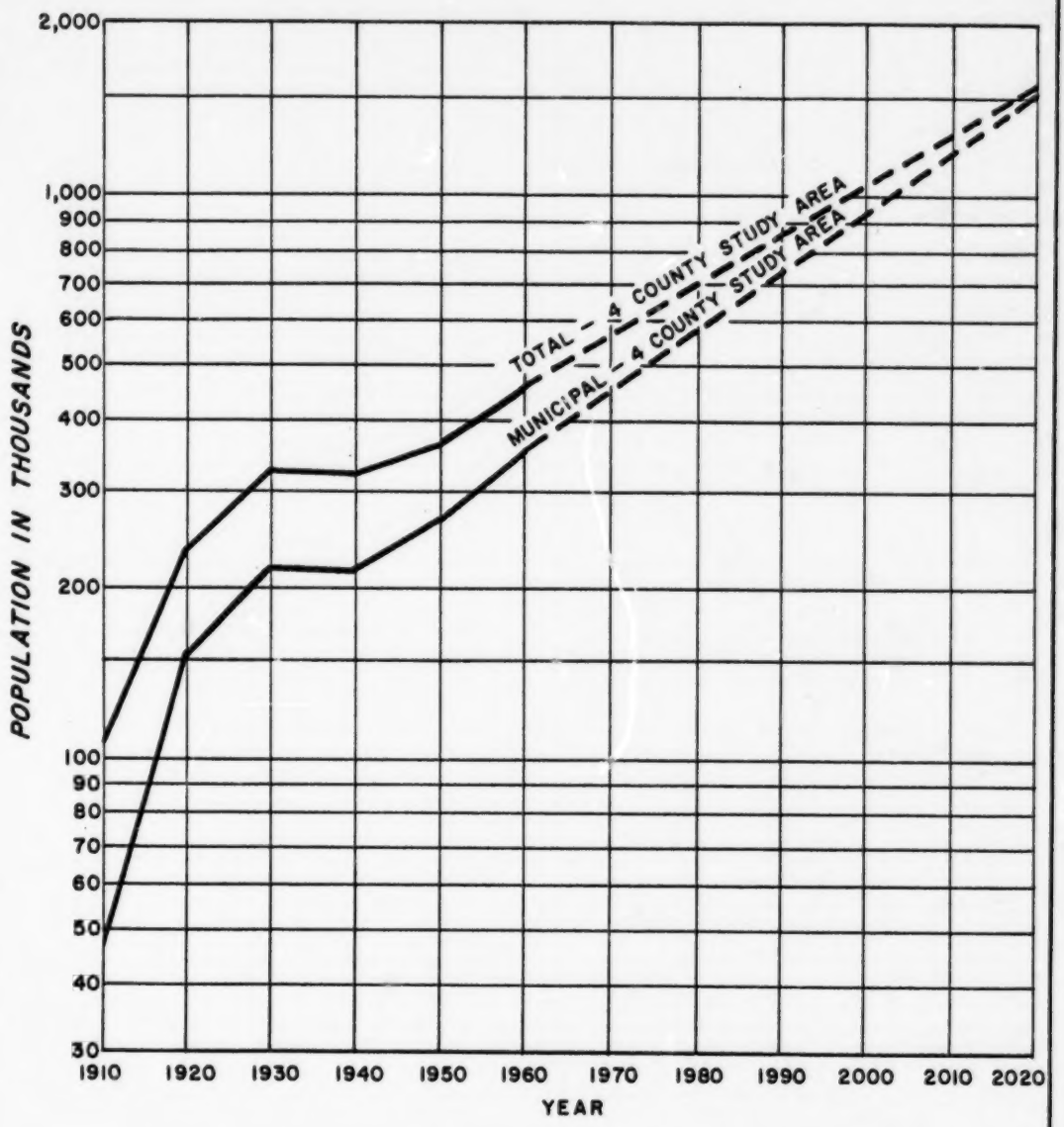
*Tulsa SMSA - Tulsa Standard Metropolitan Statistical Area, as defined by U. S. Department of Commerce, Bureau of Census, includes Tulsa, Creek, and Osage Counties.

Future Growth

From 1960 to 2020 the Nation is expected to more than double in population, producing an increased need for goods and services. The future growth of this area will depend on its ability to compete with other areas in supplying these goods and services. Details of expected growth are appended (Exhibit A).

Population Projections

Population of the study area projected to the year 2020 is 1,600,000. This represents an increase of about three and one-half times over the present population. Most of the population increase (1,530,000) is expected in areas which will be served by municipal water supply systems. See Figure 2.



SAND, COPAN, BIRCH, CANDY & SKIATOOK
RESERVOIRS-CANEY RIVER-BIRD CREEK BASINS

POPULATION TRENDS
4 COUNTY STUDY AREA

DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE 2

VI. WATER REQUIREMENTS

Past and Present Water Demand

Municipal

Historic water demand data for Tulsa are presented in Table VI-1 for the years 1950-1959. Total demand represents average quantities of water delivered to the water treatment plant including distribution system loss and treatment plant attenuation. The Tulsa municipal system supplies water to heavy water using industry (two oil refineries). The adjusted total reflects a decrease to exclude heavy industrial water demand.

Table VI-1[21/]

Tulsa Municipal Water Demand, 1950-1959

Year	Average Total Use mgd	Average Adjusted Total Use mgd	Estimated Population Served (1,000's)	Average Demand gpcd
1950	26.0	23.8	220.7	108
1951	26.0	24.1	229.0	105
1952	33.0	24.1	237.2	102
1953	34.0	25.7	245.5	105
1954	38.0	26.5	253.7	104
1955	40.2	28.7	262.0	110
1956	43.5	32.0	270.2	118
1957	40.0	28.5	278.5	102
1958	42.0	30.5	286.7	106
1959	44.3	32.8	295.0	111

Similar data for the Bartlesville municipal system indicate a per capita demand of 103 in 1959 and 101 in 1960.[21/]

Industrial

The present large industrial water demands in the area are chiefly attributed to petroleum refining, natural gas processing, and petrochemical production. The demand for those industries in 1960 was approximately 8 mgd. Of this, about 7.4 mgd was used by the oil and gas industries with the remainder being used by the petrochemical industry. Most of the present demand is for high quality water for closed system cooling.

Existing Sources

Tulsa obtains its municipal water supply from Spavinaw Lake on Spavinaw Creek, a tributary of the Grand (Neosho) River. The present source has a safe yield of 100 mgd.[22] In addition, the city has recently negotiated a 25 year agreement with the Grand River Dam Authority for 32 mgd from the Grand River.[23] Spavinaw Lake water is of high quality with total dissolved solids (TDS) approximating 115 ppm and total hardness of 90 ppm.[24] The Grand River near the Spavinaw - Tulsa Aqueduct has average total dissolved solids of 200 ppm and hardness of 140 ppm.[25]

Bartlesville also utilizes a dual source of supply, Hudson Lake on Butler Creek and Hulah Lake on Caney River. The City has a contract with the Federal Government for storage in Hulah Reservoir, which has a safe yield of 10 mgd.[23] In addition, the other source has a safe yield of 5 mgd. Lake Hudson is of good quality with total dissolved solids approximately 105 ppm and hardness of 30 ppm.[24] Caney River near Hulah Reservoir is of fairly good quality with total dissolved solids in the neighborhood of 290 ppm and hardness 190 ppm.[25] Bartlesville includes softening in its water treatment process.

Other communities in the four-county study area generally rely on limited ground water sources or small surface impoundments which are considered for the most part adequate to supply existing and future needs.

Municipal Water Demand Projections

Municipal water demand for the study area is 270 mgd, projected to the year 2020; of which 243 mgd is anticipated for the Tulsa area and the remainder (27 mgd) for the Bartlesville area. Municipal demands were estimated by multiplying the projected municipal population by a projected per capita demand figure of 175 gpcd.

Industrial Water Demand Projections

Based on anticipated activity in petroleum refining and petrochemical production, the projected (2020) industrial demand for water supply is 152 mgd.

The anticipated 2020 demand for the thermoelectric power industry is 70 mgd.

Water Quality Maintenance

Under provisions of the Federal Water Pollution Control Act, Public Law 660 as amended, in the survey or planning of a reservoir by any Federal Agency, consideration must be given to the inclusion of storage for the purpose of water quality control. It is expressly stated that such storage and water releases shall not be provided as a substitute for adequate treatment or other methods of controlling wastes at their sources.

Discharge of wastes, even when treated to the maximum economically feasible and practical limit, will cause an unsatisfactory quality condition in receiving waters whose waste assimilation capacity is exceeded. This condition occurs during periods of low flows and may be avoided by the addition of water to maintain flows at higher levels. It is essential that recognition be given to the need for flows which must prevail in receiving streams if the quality of their waters is to be maintained at acceptable levels.

Waste disposal facilities in the study area may be generally described as satisfactory under present conditions. The city of Bartlesville maintains an activated sludge plant that discharges its effluent at river mile 64 on the Caney River. There are a number of waste treatment plants in the Tulsa area, both municipally and privately owned, and discharge of wastes is divided between the Bird Creek watershed and the Arkansas River. There were five meat packing plants in this area reported to the Public Health Service and published in the 1957 Inventory of Municipal and Industrial Waste Facilities,[26] which discharge wastes to the Arkansas River.

At present, no known method of waste treatment is capable of consistently reducing biochemical oxygen demand more than 90 percent at a reasonable cost. Flow regulation must be provided to maintain acceptable quality in streams receiving wastes treated to this degree when waste assimilation capacity is exceeded. The assumption is that equal allocation of project storage for municipal and industrial water supply and flow regulation for water quality control will result in satisfactory water quality in the lower Verdigris River basin (1:1 ratio). This assumption is based on findings for water demand areas in other studies. This ratio must be adjusted for Sand and Copan Reservoirs on the Caney River watershed since Bartlesville has indicated a desire for 7.8 mgd (yield) from the Sand water supply storage.

VII. BENEFITS OF STORAGE

Evaluation Method

The Federal Inter-Agency Committee on Water Resources[28] states:

> "From an over-all public viewpoint, a municipal and industrial water supply development will be economically justified if it provides water to meet expected needs at a cost not greater than the cost of the alternative source that would likely be utilized in the absence of the project."

This principle is also used in evaluating storage for water quality control, since there is no presently widely accepted alternative to regulated stream flow for maintaining stream quality at suitable levels.

Alternative Plans

Single purpose reservoirs at the site of the multipurpose projects were adopted as alternatives to the five study projects. The other logical alternative, the Arkansas River, presently is not of suitable quality for water supply purposes and was ruled out on this basis.

Cognizance should be taken of the Arkansas - Red River Basins Water Quality Conservation Project now in progress. It is the aim of this project to devise means for improving the quality of water in these basins by elimination or control of pollution so as to make these streams suitable for water supply purposes. The availability of water supply of suitable quality from the Arkansas River at Tulsa would decrease the benefit of storage in these projects.

Alternative costs for construction, operation, and maintenance were furnished by the Corps of Engineers. 15.27/An economically useful life of 50 years and a non-Federal interest rate of 4 percent were assumed for converting capital costs to equivalent annual costs.

On this basis, the annual benefits attributable to the projects are as follows:

Reservoir	Yield -- mgd		Average Annual Benefits ($1,000)	
	Municipal & Industrial Water Supply	Flow Regulation For Quality Control	Municipal Industrial Water Supply	Flow Regulation For Quality Control
Copan	14.2	17.8	280	357
Sand	7.8*	4.2	131	70
Birch	3	3	33.5	33.5
Candy	2	2	46	46
Skiatook	14	14	327	327
Total	41	41		

One-half of the storage in the proposed projects is allocated to water quality control. Control of water quality in the lower Verdigris River basin will make available water of suitable quality throughout the basin under assumed conditions. Benefits from storage in these projects, therefore, can be considered widespread.

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IX. APPENDIX

EXHIBIT A-1

ECONOMIC ENVIRONMENT AND ECONOMIC PROJECTIONS

Economic Environment

Minerals

The study area produced 18 percent of the value of minerals in Oklahoma in 1959. 8/ Petroleum was the leading mineral produced in each of the four counties in the study area in 1959. Osage County was the leading oil producing county in the state, with Creek County being ranked fifth. Other minerals produced include natural gas, natural gas liquids, stone, clays, sand and gravel, and cement.

From 1952 through 1959, the total value of minerals extracted ranged from $69.8 million to $127.7 million annually. Most of the mineral production is found in Osage County, as illustrated in Table A-1.

The study area produced 37,280,000 bbl of petroleum in 1960. 9/ At present production rates, it is estimated that the Oklahoma reserves will last from 10 to 15 years. 10/ However, this period may be extended by new oil discoveries or by development of new methods of secondary recovery.

Table A-1 8/

Value*of Mineral Production
Four County Study Area

Year	Creek County (1,000)	Osage County (1,000)	Tulsa County (1,000)	Washington County (1,000)	Four County Total (1,000)
1952	23,667	27,620	5,606	12,952	69,845
1953	26,606	33,125	5,818	15,547	81,096
1954	27,139	36,825	6,382	16,288	86,634
1955	30,607	55,020	6,387	19,574	111,585
1956	29,077	64,239	6,637	15,695	115,648
1957	30,426	73,857	6,563	16,916	127,762
1958	28,277	68,836	6,489	17,468	121,107
1959	27,672	67,262	6,397	18,774	120,105

*Adjusted to 1954 value of the dollar.

EXHIBIT A-2

Agriculture

The study area in relation to the entire state has shown a general decline in recent years with respect to value of agricultural products. In 1944 the value of crops sold in the study area was 3 percent of the state value of crops sold. In 1959 the value of crops sold was only 1 ½ percent of the state value of crops sold. The same situation existed in livestock with the value of livestock sold in the study area, 10 percent of the state in 1944 dropping to 7 percent in 1959 value of livestock sold. 11/

The number of farms in the study area has decreased from 10,577 in 1944 to 4,584 in 1959. The acres of cropland harvested in the study area has decreased from 476,443 acres in 1944 to 191,223 acres in 1959. Value of crops and livestock have shown an increase from 1954 to 1959. This situation is illustrated in Table A-2. Although farms and acreage of cropland have decreased, the combined value of crops and livestock sold have increased in recent years. This would indicate a better use of improved technology in livestock and crops programs.

Table A-2

Agricultural Statistics
Four County Study Area 11/

Year	Number Of Farms	Acres of Cropland Harvested	Value*of Crops Sold ($1,000)	Value*of Livestock Sold ($1,000)
1944	10,577	476,443	7,086	21,159
1949	7,742	297,404	5,182	18,008
1954	5,826	244,397	3,198	17,029
1959	4,584	191,223	3,931	21,688

*Adjusted to 1954 value of the dollar.

Manufacturing

The value added by manufacturing in the study area amounts to 37 percent of the value added by manufacturing for the entire state of Oklahoma. 12/

Most of the value added comes from Tulsa as shown in Table A-3.

EXHIBIT A-3

Table A-3

Value* Added by Manufacturing [12]
Four County Study Area

Year	Creek County ($1,000)	Osage County ($1,000)	Tulsa County ($1,000)	Washington County ($1,000)	Four County Total ($1,000)
1947	8,520	4,971	115,899	7,863	137,303
1954	12,147	3,158	203,125	14,786	233,216
1958	11,013	4,000	214,912	14,881	244,806

*Adjusted to 1954 value of the dollar.

Petroleum refining and petrochemical manufacture exert the major part of the industrial demand for water supply.

The present oil refining capacity in the study area is 124,000 bbl/day. [13] This represents 29 percent of the oil refining capacity in Oklahoma. The average crude production in the study area in 1960 was 102,000 bbl/day, about 20 percent of the total state production for the year. [14]

Petrochemical production is presently about 50,000 tons per year for the study area or 12 percent of the state production. [15]

The other major industries in the study area are food and kindred products, printing and publishing, fabricated metal products, and machinery (except electrical). [12]

EXHIBIT A-4

Economic Projections

Minerals

Mineral extraction in the study area is expected to show a general decrease to 2020. The amount of this decrease will depend on the technological processes that are developed in the field of secondary recovery for petroleum extraction. Methods are now being tested which would theoretically make possible 100 percent recovery of the petroleum and natural gas potential of a field. 17/ Current processes are able to achieve about 50 percent recovery. Estimates indicate that by the year 2000, 50 percent of the crude oil processed in the United States will be imported. 18/ Therefore a general decrease of petroleum extraction is logically expected in the study area.

Agriculture

Agriculture is expected to continue in the present declining trend in number of farms and acres of cropland harvested. Improved technology and demand for agricultural products will prompt a shift to more specialized, higher value crops and livestock programs.

Manufacturing

Manufacturing is expected to be the leading industry income producing activity in the study area in 2020.

Petroleum refining and petrochemical production are anticipated as the major water using industries in 2020. Other industry development is expected but will not exert a significant water demand.

Current production in the study area is expected to increase by about three times, or from 102,000 bbl/day to 283,000 bbl/day to meet the expected increase in the national demand for petroleum products in 2020. The major portion of this refining is expected to locate in or near Tulsa. A Tulsa site offers access to local growing markets in Tulsa and Oklahoma City and access by barge travel to the large eastern markets. 19/

Since local petroleum reserves are expected to be depleted by 2020, 17/ it will be necessary to establish new supplies of crude. The following are possible sources of crude supplies that could be refined in the study area:

1. New methods of secondary recovery are expected to increase the present recoverable reserves. 17/

2. As local petroleum reserves are depleted, refineries will obtain crude from other areas. This can be accomplished through the vast system of oil and gas pipe lines now established, and future lines. Large quantities of shale oil may be developed in the Colorado River basin. Crude petroleum may also be brought in by barge from other regions.

The national demand for petrochemicals prorated to the study area would be 2.5 million tons in 2020. 15,20/ Factors supporting this increase are:

1. The nearby and readily available supply of raw material from refineries and/or gas fields.

2. A plentiful supply of cheap natural gas for fuel.

3. Ample process materials such as salt, sulphur, and lime.

4. Future access to water transportation.

5. A good agricultural area, a market for petrochemical fertilizers.

6. Good highway and rail transportation for shipment of goods to regional markets.

7. Sufficient amount of qualified labor personnel.

X-1

EXHIBIT B-1

ALTERNATIVE COST AND VALUE COMPUTATIONS

The following table summarizes the alternative cost computations used for determining the value of storage in the five study projects.

Table B-1

Summary of Alternative Cost Computations

	Copan	Sand	Birch	Candy	Skiatook
First [a/] Cost	13,158	3,754	1,071	1,433	13,120
2-year [a/] Construction Investment ($1,000)	395	---	---	---	394
Total Initial Investment ($1,000)	13,553	3,754	1,071	1,443	13,514
Annual Cost Amortized 50 yr. @ 4 Percent ($1,000)	612	175	50	67	629
Annual [a/] Operations & Maintenance Cost ($1,000)	25	26	17	25	25
Total Annual Cost ($1,000)	637	201	67	92	654
Yield [a/] mgd	32	12	6	4	28

[a/] Data from Corps of Engineers, U. S. Army Engineer District, Tulsa.